An Integrated Hydrogen Production-CO_2 Capture Process from Fossil Fuel

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Principal Authors: Z. Wang (PI) and K. B. Bota
Clark Atlanta University, Atlanta, GA 30314
Email: zwang@cau.edu Phone: 404-880-6934

D. Day
Scientific Carbons Inc, Blakely, GA

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ABSTRACT

The major project objective is to determine the feasibility of using the char from coal and/or biomass pyrolysis, ammonia and CO2 emissions at smokestacks to produce clean hydrogen and a sequestered carbon fertilizer. During this work period, literature review has been completed. The project plan, design and test schedules were made on the basis of discussion with partner in experimental issues. Installation of pilot scale units was finished and major units tests were fully performed. Modification of the pyrolyzer, reformer and gas absorption tank have been done. Integration testing is performing recently. Lab scale tests are in operation phase. The experimental installations are discussed in this paper.

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INTRODUCTION AND OBJECTIVES

The increasing anthropogenic CO_2 emissions and possible global warning have challenged the United States and other countries to find new and better ways to meet the world's increasing need for energy while, at the same time, reducing greenhouse gas emissions. The improved technology for integrated hydrogen production/CO2 capture that we plan to develop through this R&D effort could significantly support President Bush's Global Climate Change Initiative (GCCI) that commits America to an aggressive strategy to reduce greenhouse gas intensity by 18 percent over the next 10 years. Our new technology concept integrates two significant and complementary hydrogen production and CO_2-sequestration approaches that have now been developed at Oak Ridge National Laboratory (ORNL) and Clark Atlanta University.

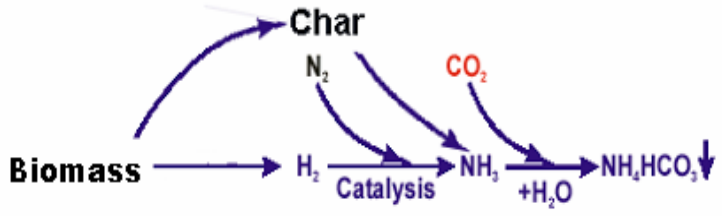

Figure 1 Schematic View of the process from Biomass to Fertilizer

Figure 1 illustrates the schematic view of the process of converting biomass into hydrogen and char. Hydrogen can be efficiently used for stationary power and mobile applications, or it can be synthesized into ammonia, while char can be used for making time-release fertilizers (NH_4HCO_3) by absorption of CO_2 and other acid gases from exhaust flows. Fertilizers are then used for the growth of biomass

The objective of the proposed study is to determine the feasibility of using the char from a coal and/or biomass pyrolysis-reforming process and CO_2 emissions at a

smokestake to form a solid NH_4HCO_3-char product that can subsequently be used as a fertilizer. Part of the hydrogen from the pyrolysis-reforming process may be converted to ammonia that is used to solidify the CO_2 as NH_4HCO_3 in the char. The balance of the hydrogen may be purified and sold at market prices or used as a feedstock.

This project plans to perform bench scale experiments and pilot scale tests. The Combustion and Emission Lab at Clark Atlanta University has conducted the bench scale experiments. The facility used for pilot scale tests has built in Athens, GA.

EXPERIMENTAL FACILITIES

Part A Hydrogen and char production

Our integrated process consists of two stages: 1) pyrolysis of biomass to generate pyrolysis gas/char, and 2) catalytic steam reforming of pyrolysis gas. Figure 2 shows the schematic flow diagram of the developed process. The flow procedure of the process is as follows: Feeder accepts biomass; the pyrolysis unit pyrolyzes the biomass into pyrolysis gas and char at around 500°C; char is leaked out at this stage, while pyrolysis gas flows into baghouse to filter out solid components accompanied with pyrolysis gas; before the gas is introduced into catalytic reformer, the pyrolysis gas is heated up to 680°C; in the reformer at 850°C, most of pyrolysis gas is finally converted into hydrogen, carbon dioxide and water; after condensed and cooled down the water vapor, the mixtures of hydrogen and carbon dioxide, along with the nitrogen and other gases at normal temperature are produced. Hydrogen can be purified from the mixed gases. In our experiments, hydrogen is burned at the exit.

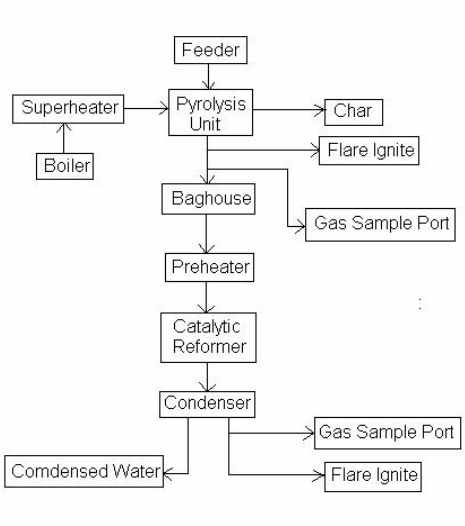

Figure 2 Schematic Flow Diagram of Char and Hydrogen Production

A photo of the pyrolysis unit of the pilot scale plant is shown in Figure 3. Char is led out from bottom of this unit.

Figure 3 Pyrolysis Unit with Biomass feedstack system

Part B Fertilizer production

The next step after char produced is to make fertilizer. Figure 4 is the Schematic diagram of the bench scale experiments for NH_3-CO_2 solidification. Before the NH_3 and CO_2

Introduced into the reactor, the char (activated carbon) needs to be mixed with water at various ratios and filled into the reactor. Then, the reactants (NH_3 and CO_2) flow into the reactor to form a solid NH_4HCO_3-char product that may subsequently be used as a fertilizer. The flow rates of each gas are controlled by MKS flow controllers. The remaining ammonia is absorbed in water bath, while carbon dioxide can be monitored by Agilent Micro GC.

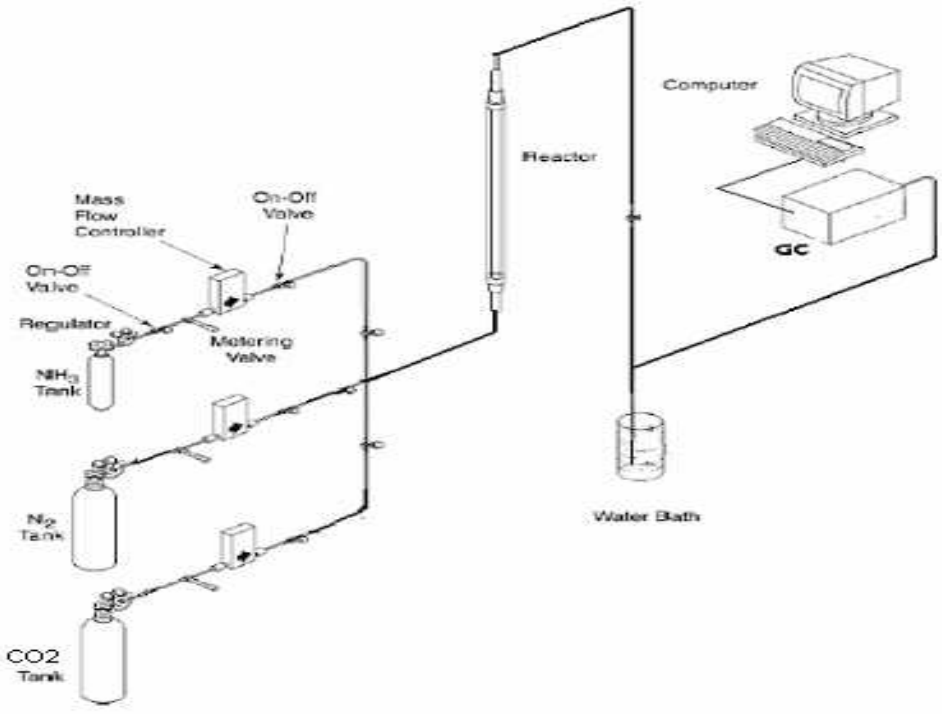

Figure 4 Schematic of Bench Scale Test of NH_3-CO_2 solidification

Figure 5 shows the fertilizer reactor for the bench scale experiments. The 1/3 reactor is filled with wet char (20g). After reaction, 3-7 gram of NH_4HCO_3 can be formed.

Figure 5 Photo of Bench Scale Test

RESULTS AND DISCUSSION

The Char and Hydrogen production experiments have been done. Figure 6 illustrates the dry N_2-free basis gas composition during a 24-hours operation. It is the final output gas that excludes nitrogen and water. During the 24-hours continuous operation of experiment, 48% (at dry N_2-free basis) of hydrogen is obtained from the integration system. Other major components are 35% carbon dioxide, 9% methane and 8% carbon monoxide. Using peanut shells as feedstock, the overall yield from this system is up to 6wt% hydrogen and 32wt% charcoal/activated carbon.

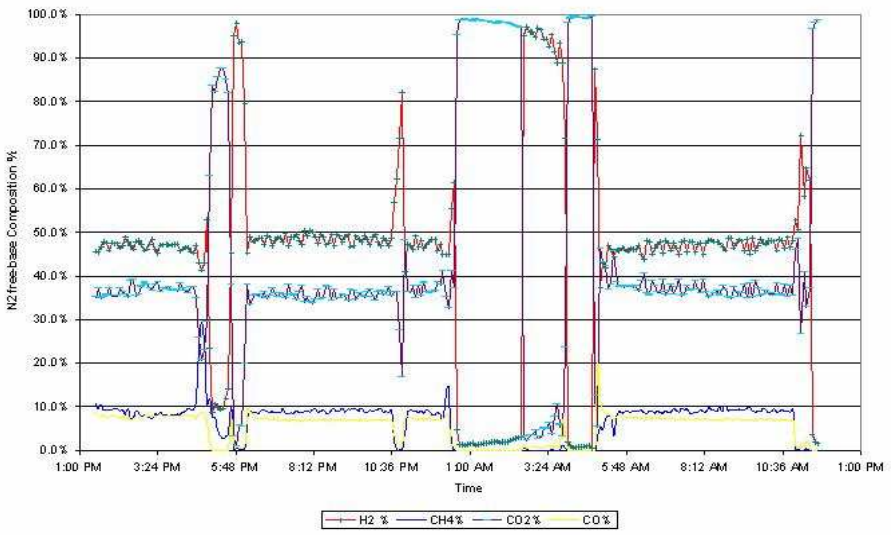

Figure 6 Dry N_2-free basis gas compositions via Time

The pyrolysis unit has produced char samples, which planed to use as the sequestration material. Figure 7 is the photo of sample char material.

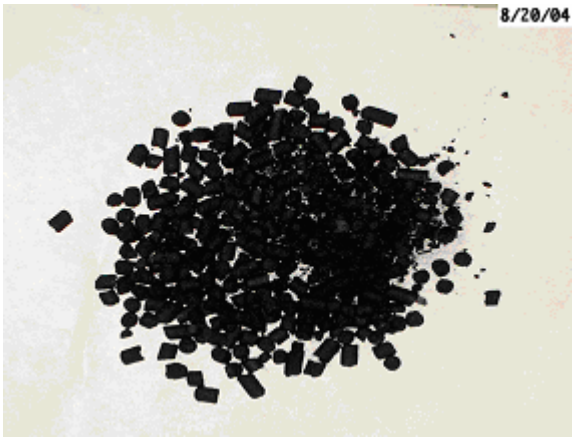

Figure 7 Char material produced by the Pyrolyzer

Figure 8 is the result of investigation of the leaching examination of different chars, which are produced with different exit temperatures, from 400°C-900°C. This figure shows that the 400°C char has the potential of long term slow release of nutrients, hinting good candidate for a time-release fertilizer.

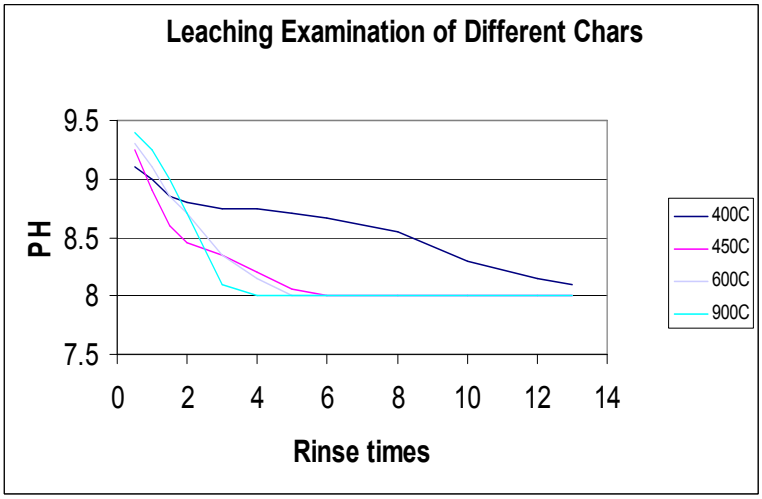

Figure 8 leaching examination of different chars.

Since the char around exit temperature 400°C is good to keep fertilizer time-release. We tested the fertilizer absorption of the char around this temperature (380°C-420°C). Figure 9 shows that the 380°C-420°C chars have similar absorbability and 400°C char is little better.

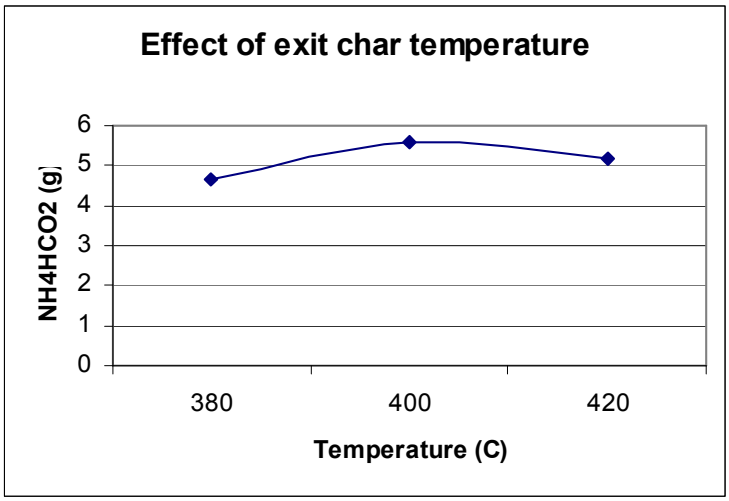

Figure 9 Effect of exit char temperature

Figure 10 illustrates the formation of Ammonium Bicarbonate (NH_4HCO_3) Char Production.

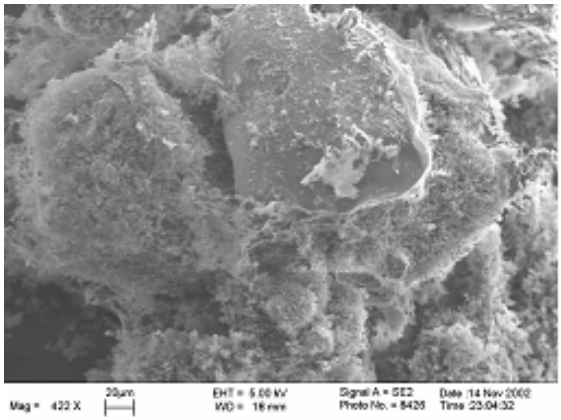

Figure 10 Photo of formation of Ammonium Bicarbonate

FUTURE PLANS

In the past few months, we have finished the char and hydrogen production experiments, produced char samples, built the setup of bench scale experiments, and initiated the characteristic analysis of char products. The future works include the following tasks.

1. Testing, Analysis an characterization of the char and gaseous products
2. Process optimization
3. NH_3-CO_2 solidification process
4. Tests to evaluate fertilizer usage

CONCLUSIONS

1. The pilot scale hydrogen and char production tests have completed.
2. The bench scale equipment has conducted.
3. The pilot scale facilities are installed and finished char and hydrogen production tests

4. Primary investigation to char characteristics has been conducted.
5. The future works include NH_3-CO_2 solidification and tests to evaluate fertilizer usage.

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